Fig. 1

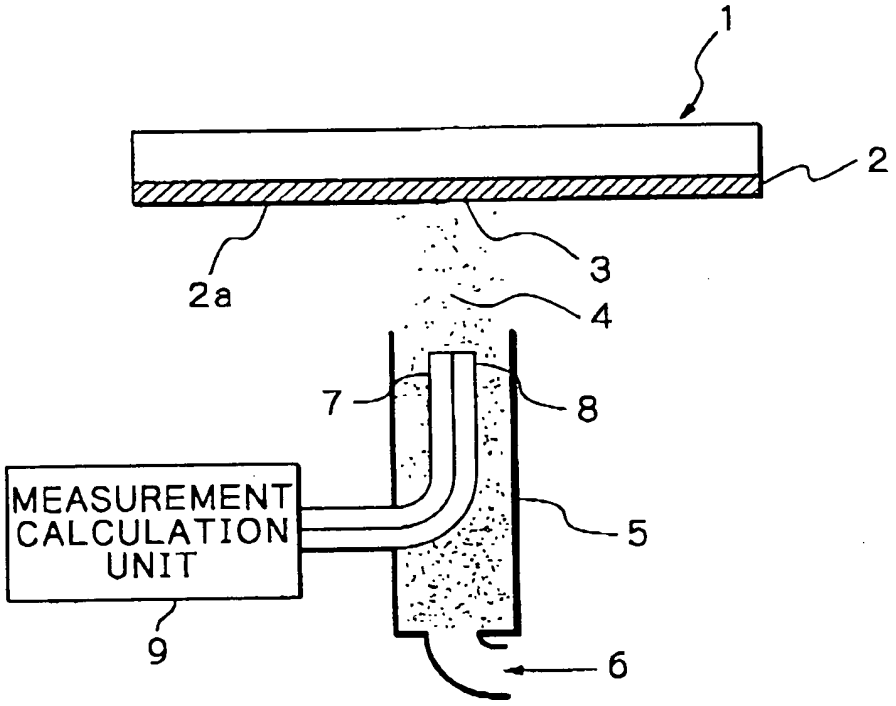


Fig. 2

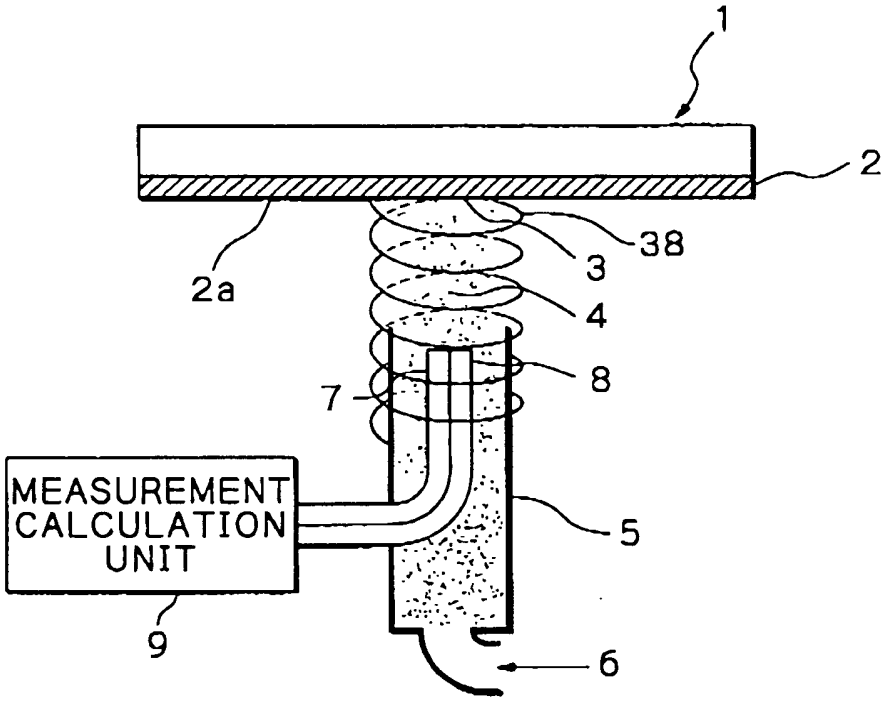


Fig. 3

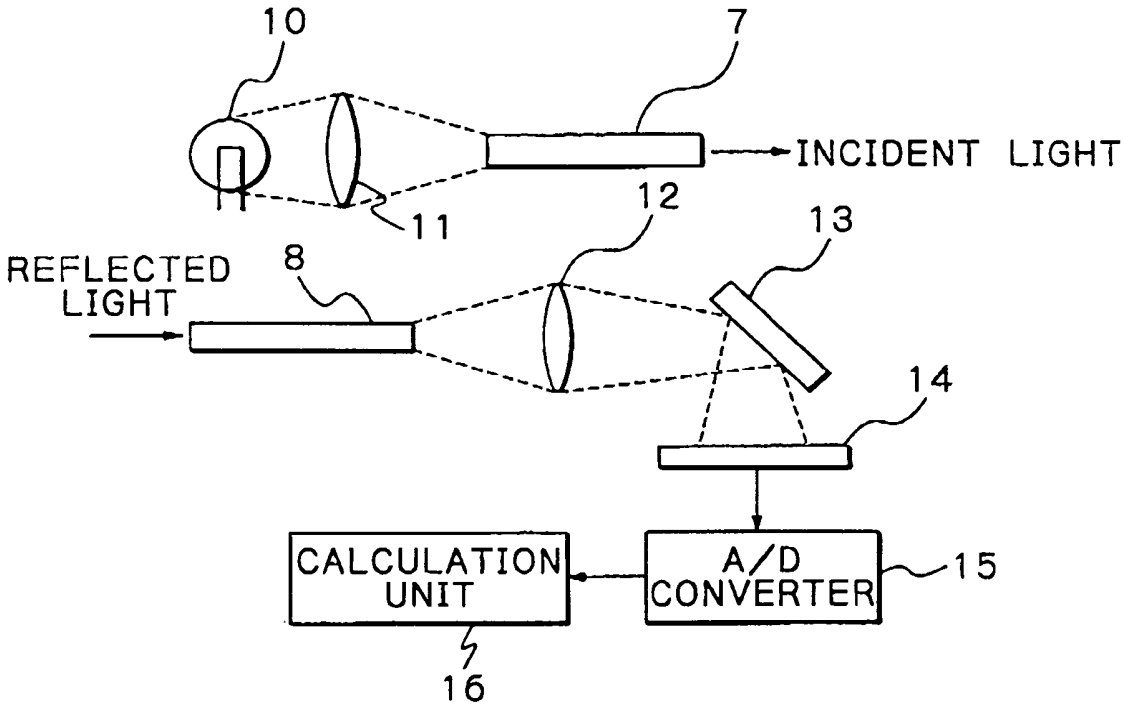

10
7
INCIDENT LIGHT
11
12
13
REFLECTED LIGHT
8
14
CALCULATION UNIT
A/D CONVERTER
15
16

Fig. 4

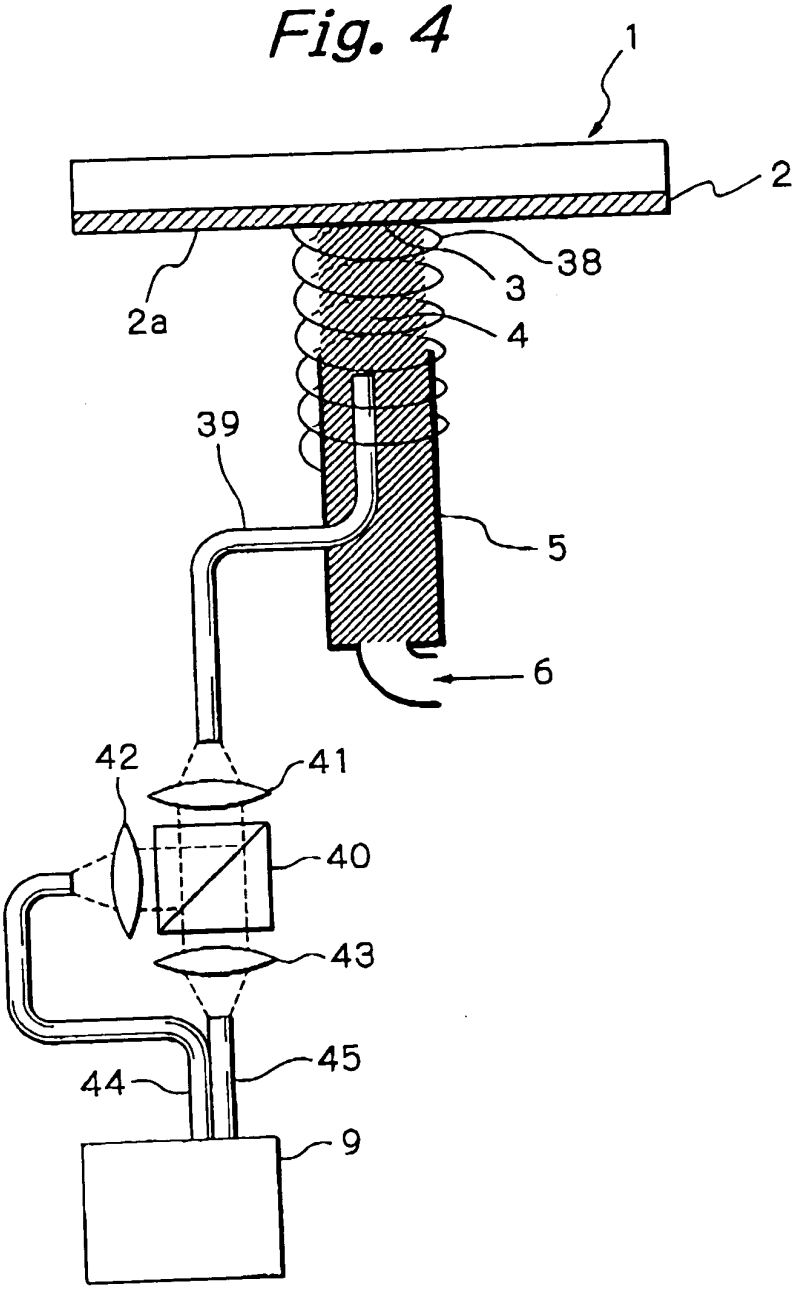


Fig. 5

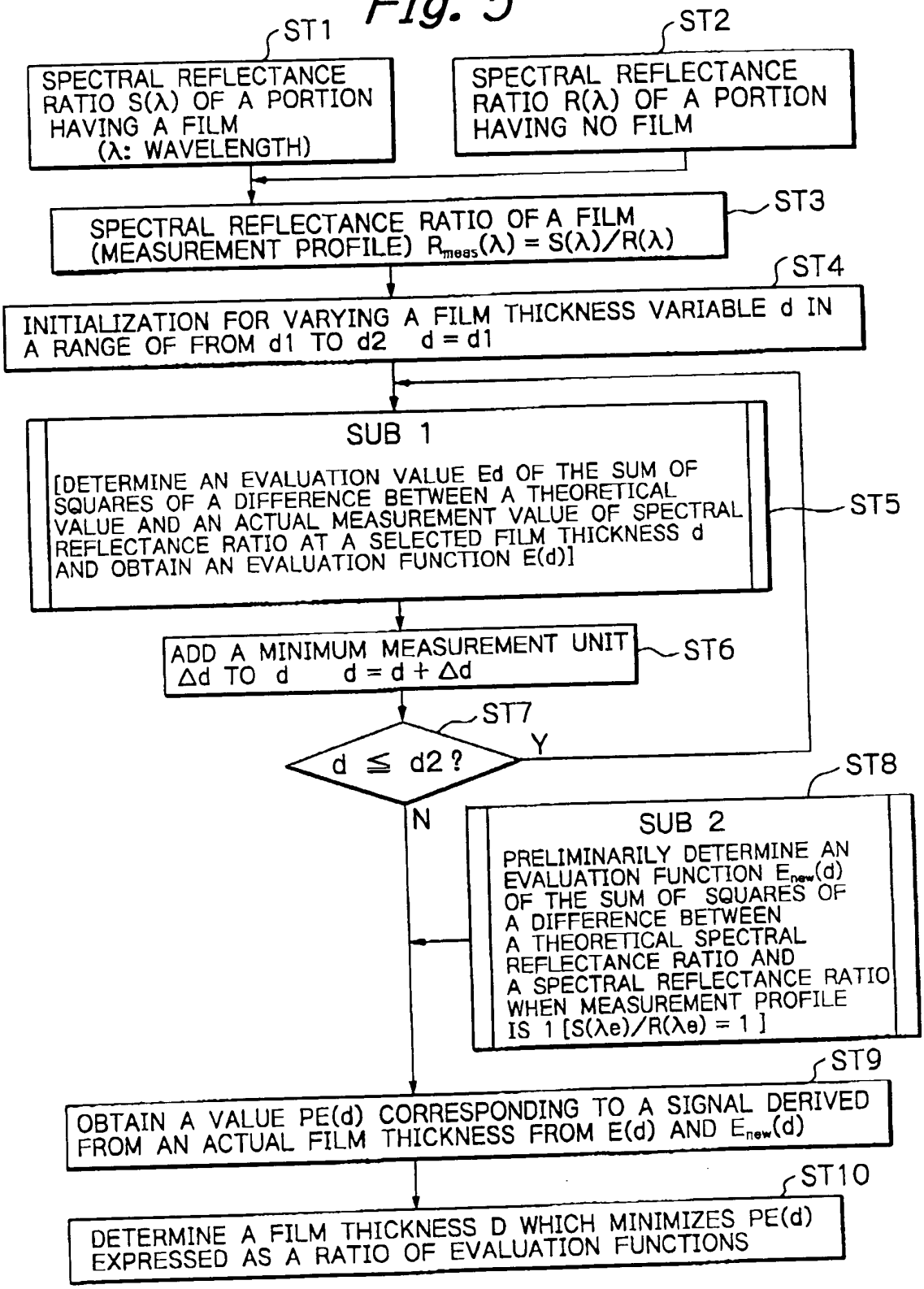

ST1
SPECTRAL REFLECTANCE RATIO S(λ) OF A PORTION HAVING A FILM (λ: WAVELENGTH)
ST2
SPECTRAL REFLECTANCE RATIO R(λ) OF A PORTION HAVING NO FILM
SPECTRAL REFLECTANCE RATIO OF A FILM (MEASUREMENT PROFILE) $R_{meas}(\lambda) = S(\lambda)/R(\lambda)$
ST3
ST4
INITIALIZATION FOR VARYING A FILM THICKNESS VARIABLE d IN A RANGE OF FROM d1 TO d2 d = d1
SUB 1
[DETERMINE AN EVALUATION VALUE Ed OF THE SUM OF SQUARES OF A DIFFERENCE BETWEEN A THEORETICAL VALUE AND AN ACTUAL MEASUREMENT VALUE OF SPECTRAL REFLECTANCE RATIO AT A SELECTED FILM THICKNESS d AND OBTAIN AN EVALUATION FUNCTION E(d)]
ST5
ADD A MINIMUM MEASUREMENT UNIT Δd TO d d = d + Δd
ST6
ST7
d ≦ d2 ?
Y
N
ST8
SUB 2
PRELIMINARILY DETERMINE AN EVALUATION FUNCTION $E_{new}(d)$ OF THE SUM OF SQUARES OF A DIFFERENCE BETWEEN A THEORETICAL SPECTRAL REFLECTANCE RATIO AND A SPECTRAL REFLECTANCE RATIO WHEN MEASUREMENT PROFILE IS 1 [$S(\lambda e)/R(\lambda e) = 1$]
ST9
OBTAIN A VALUE PE(d) CORRESPONDING TO A SIGNAL DERIVED FROM AN ACTUAL FILM THICKNESS FROM E(d) AND $E_{new}(d)$
ST10
DETERMINE A FILM THICKNESS D WHICH MINIMIZES PE(d) EXPRESSED AS A RATIO OF EVALUATION FUNCTIONS

Fig. 6

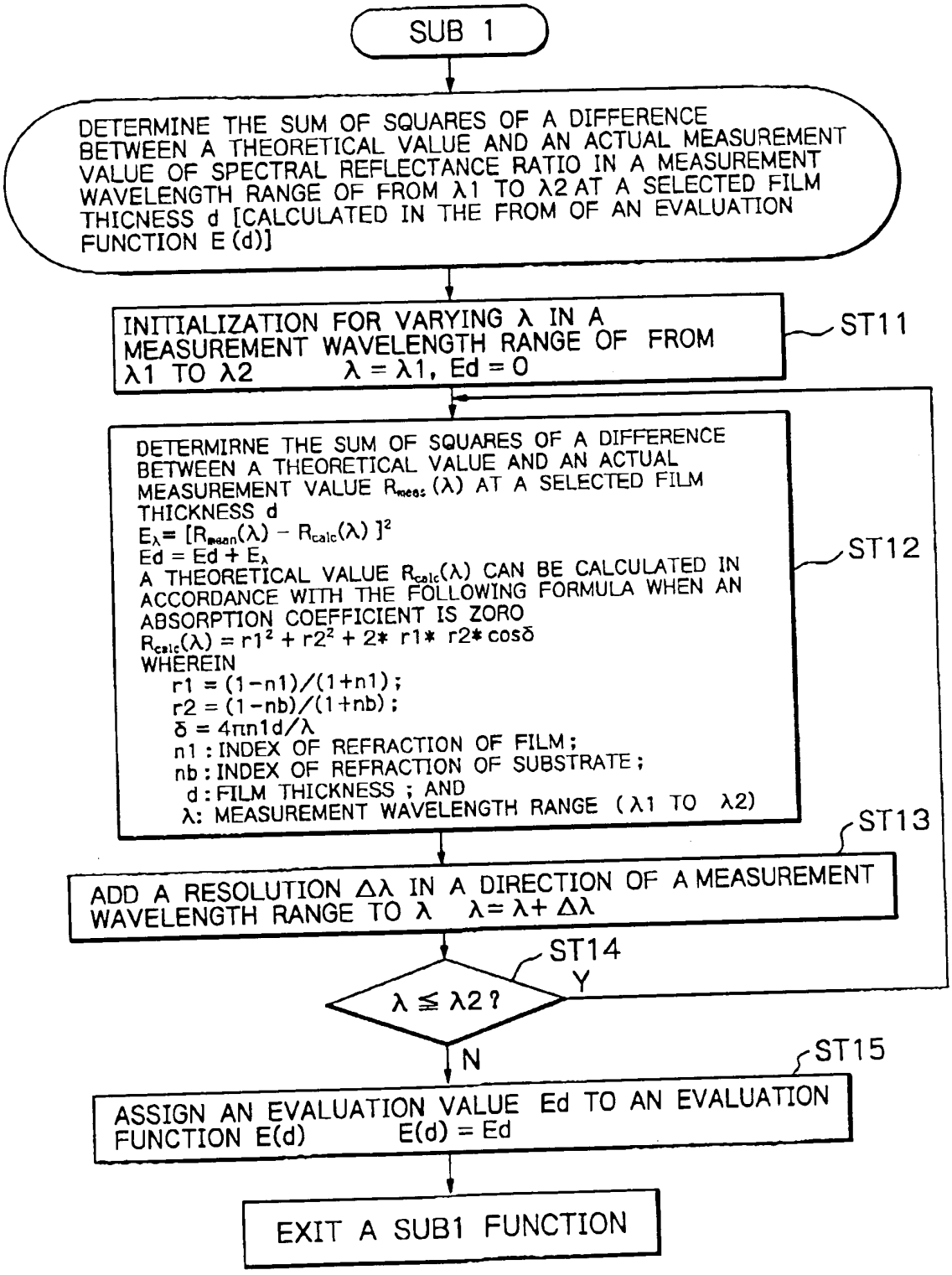

SUB 1
DETERMINE THE SUM OF SQUARES OF A DIFFERENCE BETWEEN A THEORETICAL VALUE AND AN ACTUAL MEASUREMENT VALUE OF SPECTRAL REFLECTANCE RATIO IN A MEASUREMENT WAVELENGTH RANGE OF FROM λ1 TO λ2 AT A SELECTED FILM THICNESS d [CALCULATED IN THE FROM OF AN EVALUATION FUNCTION E(d)]
INITIALIZATION FOR VARYING λ IN A MEASUREMENT WAVELENGTH RANGE OF FROM λ1 TO λ2 λ = λ1, Ed = 0
ST11
DETERMIRNE THE SUM OF SQUARES OF A DIFFERENCE BETWEEN A THEORETICAL VALUE AND AN ACTUAL MEASUREMENT VALUE $R_{meas}(\lambda)$ AT A SELECTED FILM THICKNESS d
$E_\lambda = [R_{mean}(\lambda) - R_{calc}(\lambda)]^2$
$Ed = Ed + E_\lambda$
A THEORETICAL VALUE $R_{calc}(\lambda)$ CAN BE CALCULATED IN ACCORDANCE WITH THE FOLLOWING FORMULA WHEN AN ABSORPTION COEFFICIENT IS ZORO
$R_{calc}(\lambda) = r1^2 + r2^2 + 2 * r1 * r2 * \cos\delta$
WHEREIN
r1 = (1−n1)/(1+n1);
r2 = (1−nb)/(1+nb);
δ = 4πn1d/λ
n1 : INDEX OF REFRACTION OF FILM;
nb : INDEX OF REFRACTION OF SUBSTRATE;
d : FILM THICKNESS ; AND
λ: MEASUREMENT WAVELENGTH RANGE (λ1 TO λ2)
ST12
ADD A RESOLUTION Δλ IN A DIRECTION OF A MEASUREMENT WAVELENGTH RANGE TO λ λ = λ + Δλ
ST13
λ ≦ λ2 ?
ST14
Y
N
ASSIGN AN EVALUATION VALUE Ed TO AN EVALUATION FUNCTION E(d) E(d) = Ed
ST15
EXIT A SUB1 FUNCTION

Fig. 7

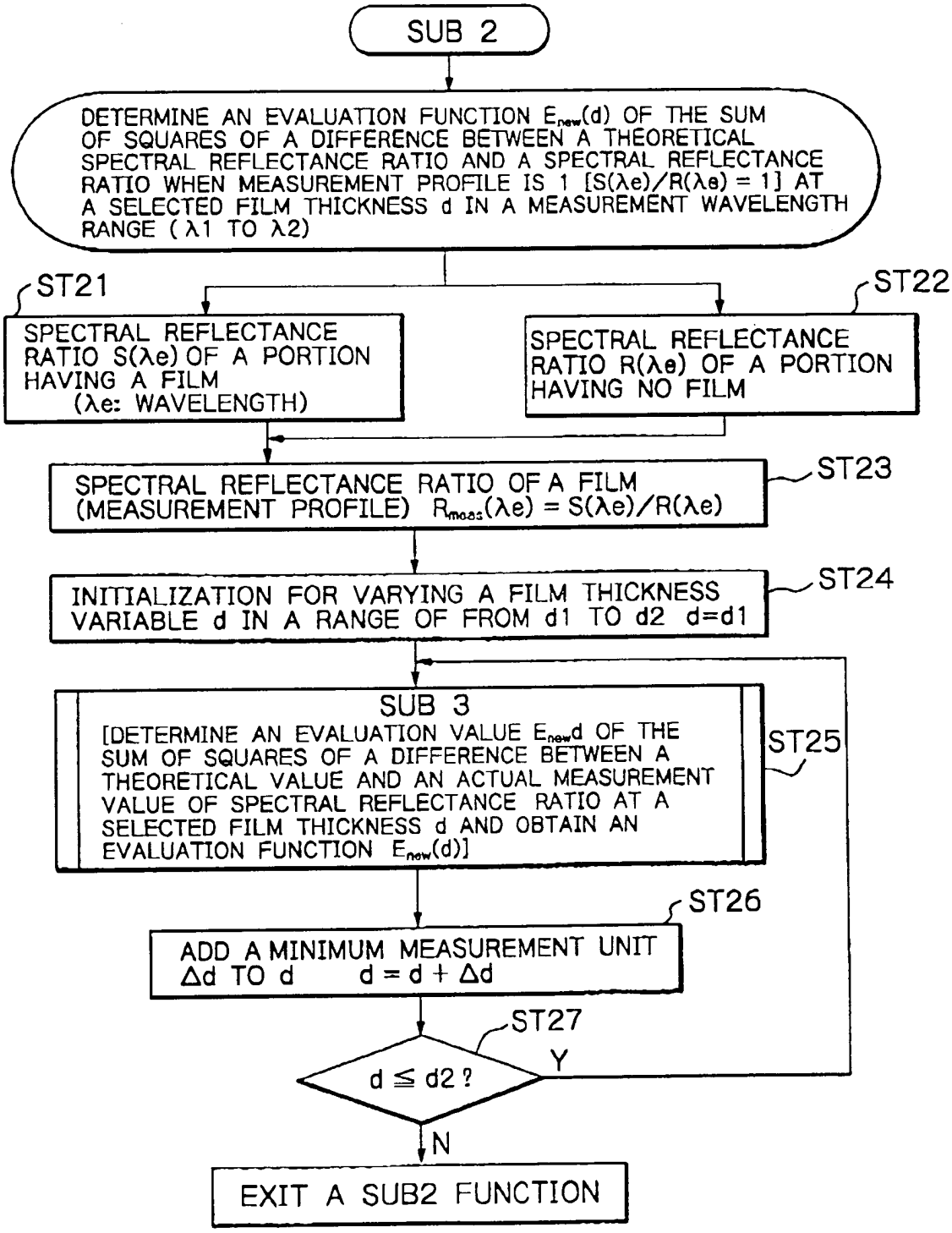

SUB 2
DETERMINE AN EVALUATION FUNCTION $E_{new}(d)$ OF THE SUM OF SQUARES OF A DIFFERENCE BETWEEN A THEORETICAL SPECTRAL REFLECTANCE RATIO AND A SPECTRAL REFLECTANCE RATIO WHEN MEASUREMENT PROFILE IS 1 [$S(\lambda e)/R(\lambda e) = 1$] AT A SELECTED FILM THICKNESS d IN A MEASUREMENT WAVELENGTH RANGE ($\lambda 1$ TO $\lambda 2$)
ST21
SPECTRAL REFLECTANCE RATIO $S(\lambda e)$ OF A PORTION HAVING A FILM (λe: WAVELENGTH)
ST22
SPECTRAL REFLECTANCE RATIO $R(\lambda e)$ OF A PORTION HAVING NO FILM
SPECTRAL REFLECTANCE RATIO OF A FILM (MEASUREMENT PROFILE) $R_{meas}(\lambda e) = S(\lambda e)/R(\lambda e)$
ST23
INITIALIZATION FOR VARYING A FILM THICKNESS VARIABLE d IN A RANGE OF FROM d1 TO d2 d=d1
ST24
SUB 3
[DETERMINE AN EVALUATION VALUE $E_{new}d$ OF THE SUM OF SQUARES OF A DIFFERENCE BETWEEN A THEORETICAL VALUE AND AN ACTUAL MEASUREMENT VALUE OF SPECTRAL REFLECTANCE RATIO AT A SELECTED FILM THICKNESS d AND OBTAIN AN EVALUATION FUNCTION $E_{new}(d)$]
ST25
ADD A MINIMUM MEASUREMENT UNIT Δd TO d $d = d + \Delta d$
ST26
ST27
$d \leq d2$?
Y
N
EXIT A SUB2 FUNCTION

Fig. 8

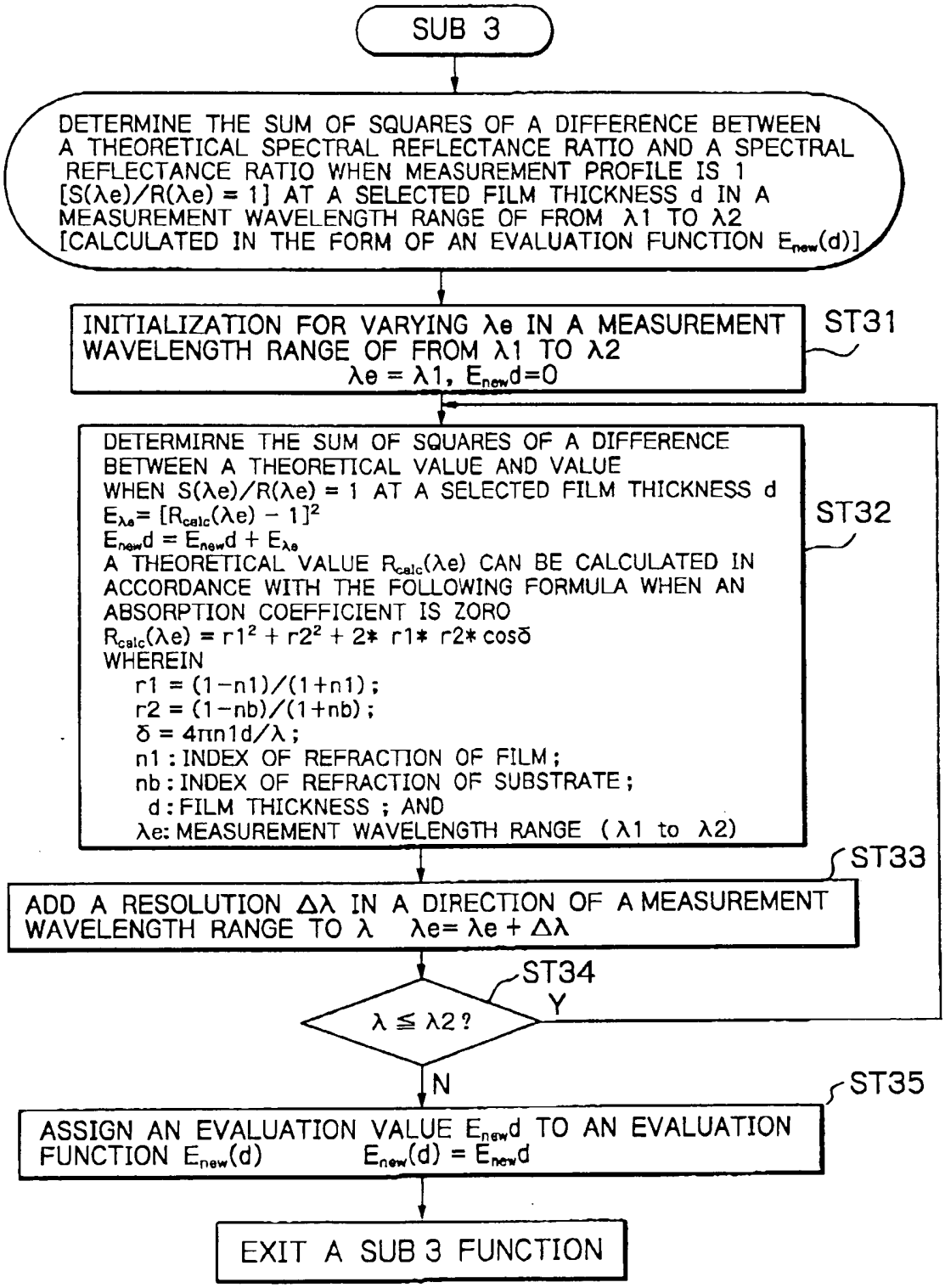

SUB 3
DETERMINE THE SUM OF SQUARES OF A DIFFERENCE BETWEEN A THEORETICAL SPECTRAL REFLECTANCE RATIO AND A SPECTRAL REFLECTANCE RATIO WHEN MEASUREMENT PROFILE IS 1 [S(λe)/R(λe) = 1] AT A SELECTED FILM THICKNESS d IN A MEASUREMENT WAVELENGTH RANGE OF FROM λ1 TO λ2 [CALCULATED IN THE FORM OF AN EVALUATION FUNCTION Enew(d)]
INITIALIZATION FOR VARYING λe IN A MEASUREMENT WAVELENGTH RANGE OF FROM λ1 TO λ2
λe = λ1, Enewd=0
ST31
DETERMIRNE THE SUM OF SQUARES OF A DIFFERENCE BETWEEN A THEORETICAL VALUE AND VALUE WHEN S(λe)/R(λe) = 1 AT A SELECTED FILM THICKNESS d
Eλe= [Rcalc(λe) − 1]2
Enewd = Enewd + Eλe
A THEORETICAL VALUE Rcalc(λe) CAN BE CALCULATED IN ACCORDANCE WITH THE FOLLOWING FORMULA WHEN AN ABSORPTION COEFFICIENT IS ZORO
Rcalc(λe) = r1² + r2² + 2* r1* r2* cosδ
WHEREIN
r1 = (1−n1)/(1+n1);
r2 = (1−nb)/(1+nb);
δ = 4πn1d/λ;
n1 : INDEX OF REFRACTION OF FILM;
nb : INDEX OF REFRACTION OF SUBSTRATE;
d : FILM THICKNESS ; AND
λe: MEASUREMENT WAVELENGTH RANGE (λ1 to λ2)
ST32
ADD A RESOLUTION Δλ IN A DIRECTION OF A MEASUREMENT WAVELENGTH RANGE TO λ λe= λe + Δλ
ST33
λ ≦ λ2 ?
ST34
Y
N
ASSIGN AN EVALUATION VALUE Enewd TO AN EVALUATION FUNCTION Enew(d) Enew(d) = Enewd
ST35
EXIT A SUB 3 FUNCTION

Fig. 9

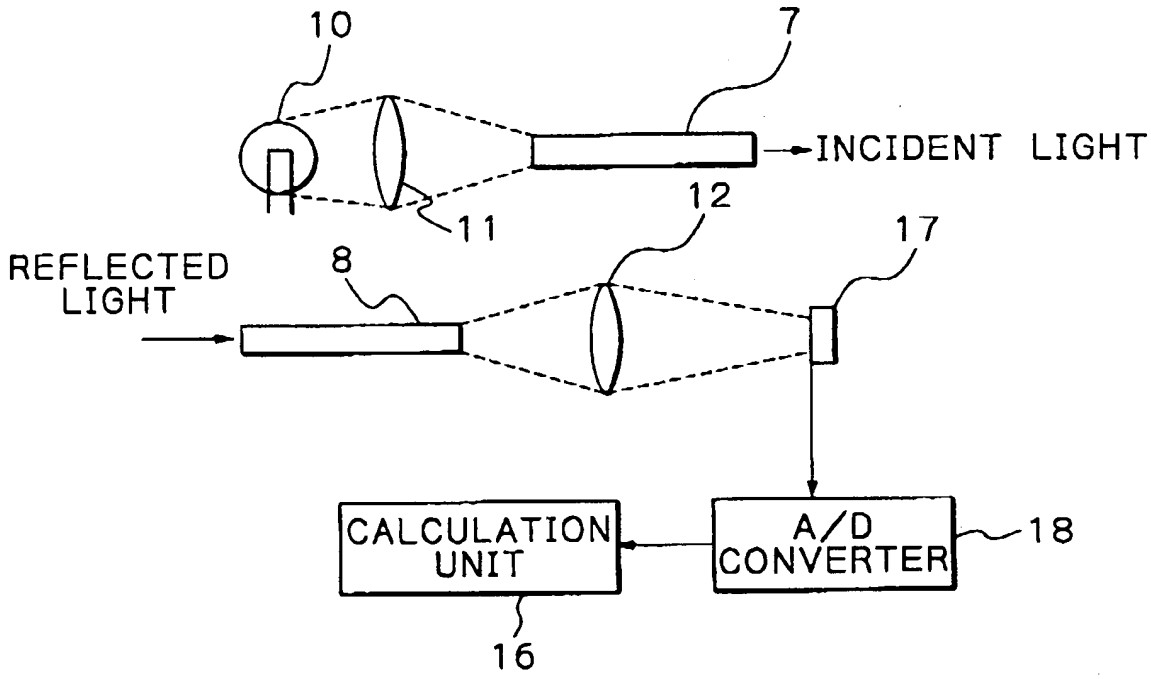

10
7
INCIDENT LIGHT
12
11
17
REFLECTED LIGHT
8
CALCULATION UNIT
A/D CONVERTER
18
16

Fig. 10

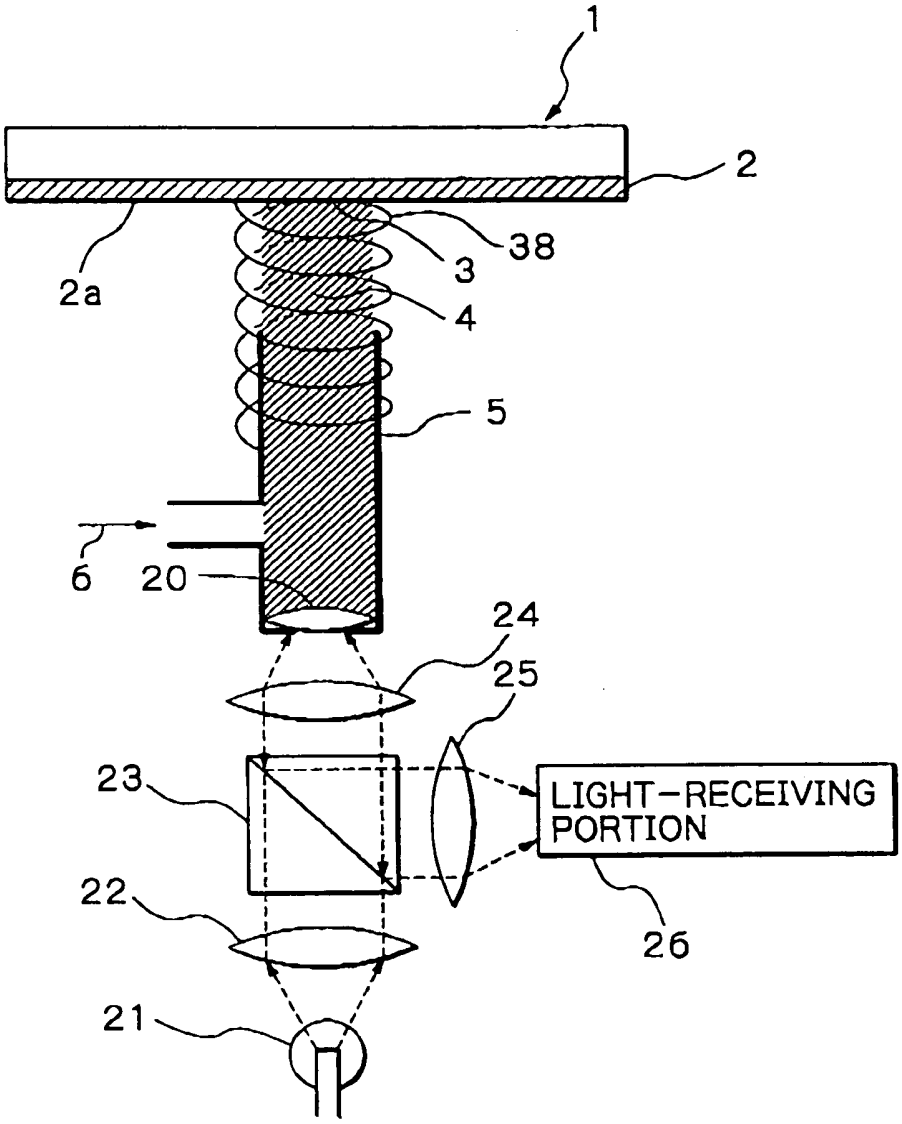


Fig. 11

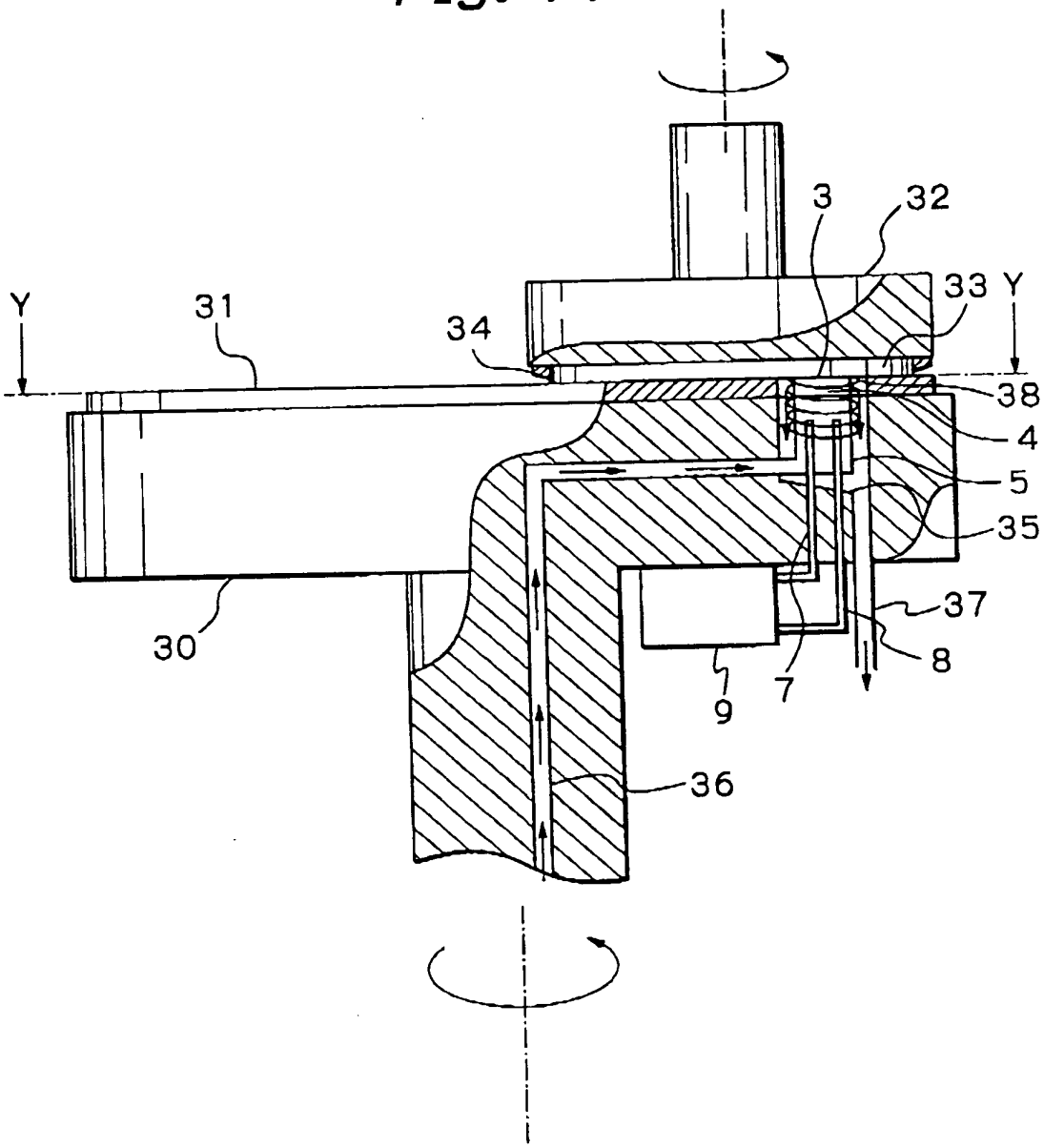
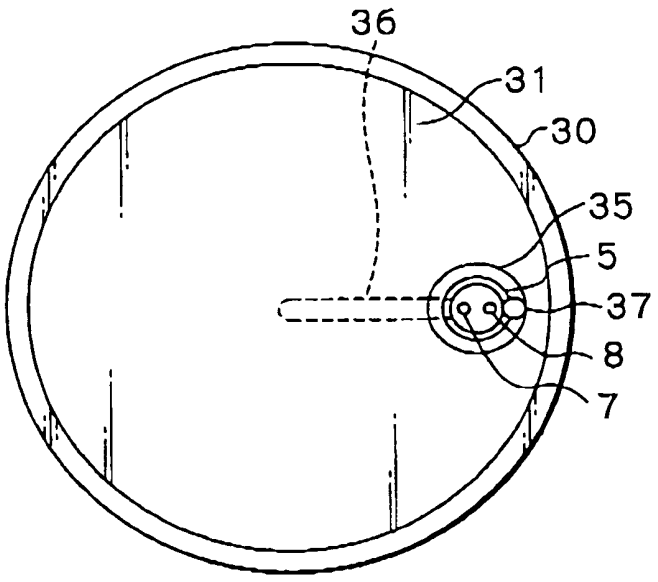


Fig. 12



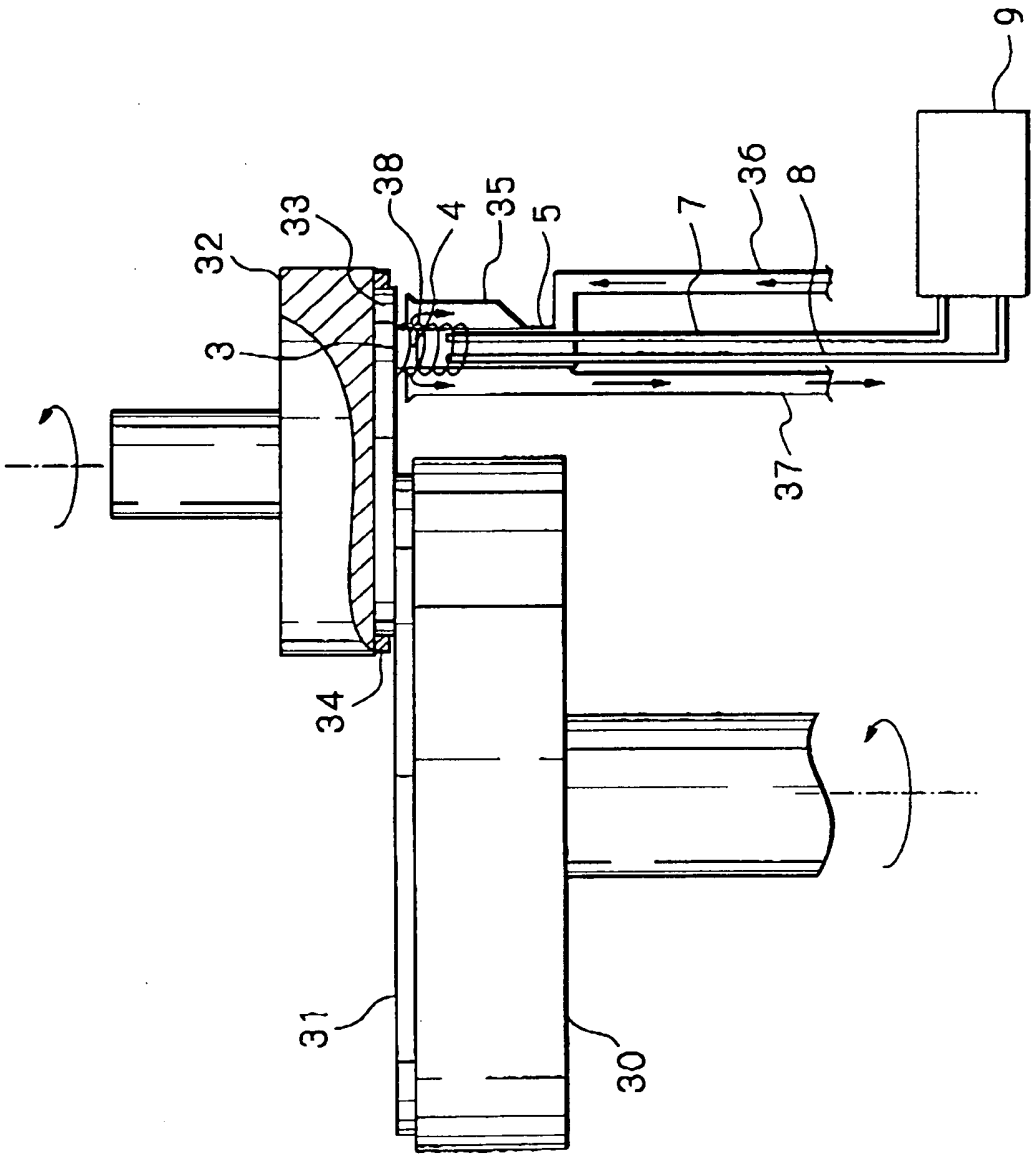


Fig. 13

Fig. 14

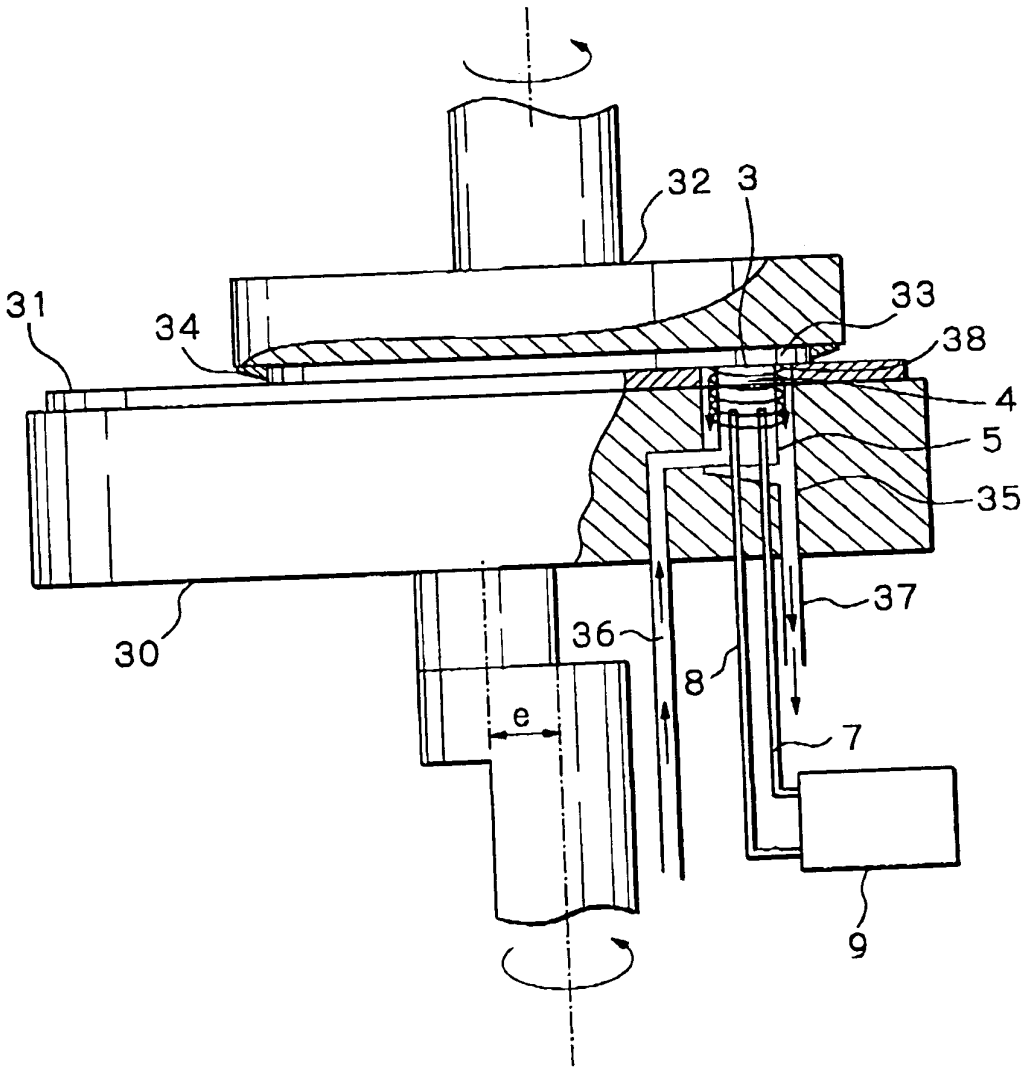


Fig. 15

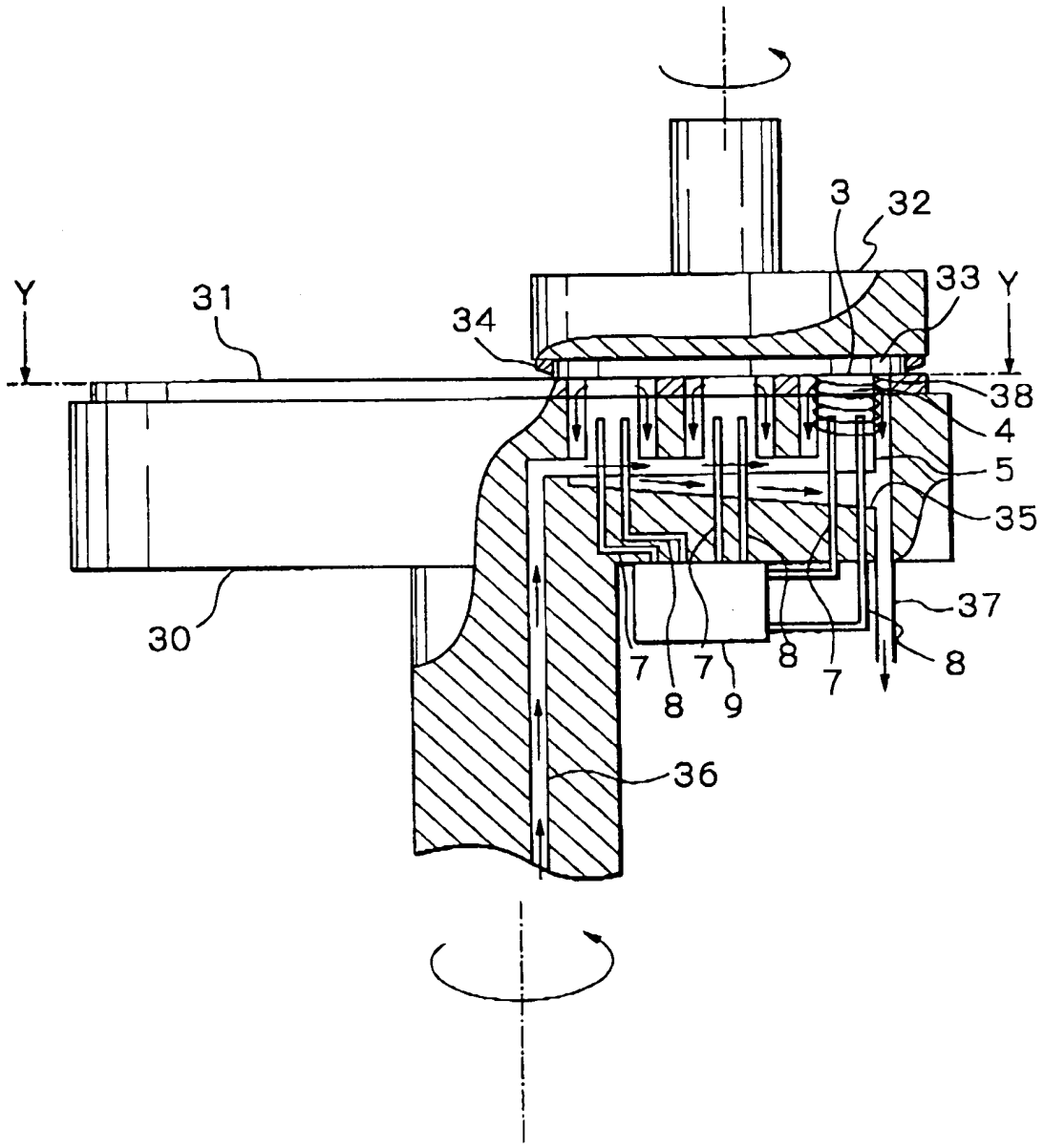


Fig. 16

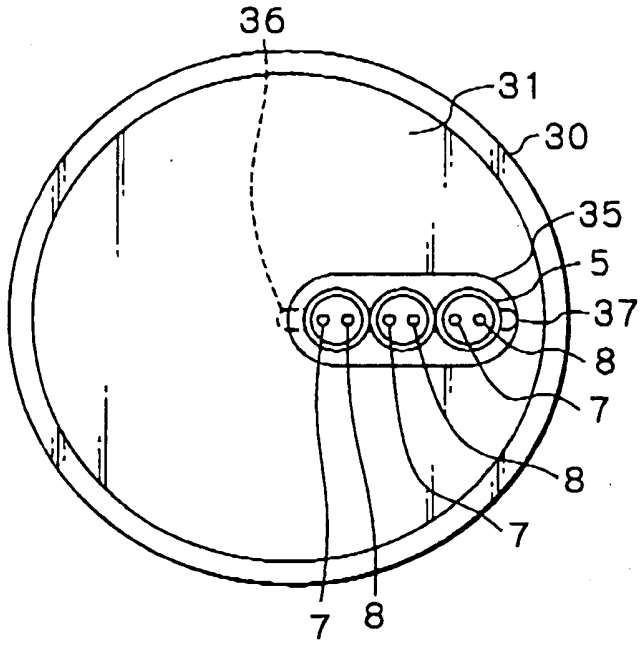


Fig. 17

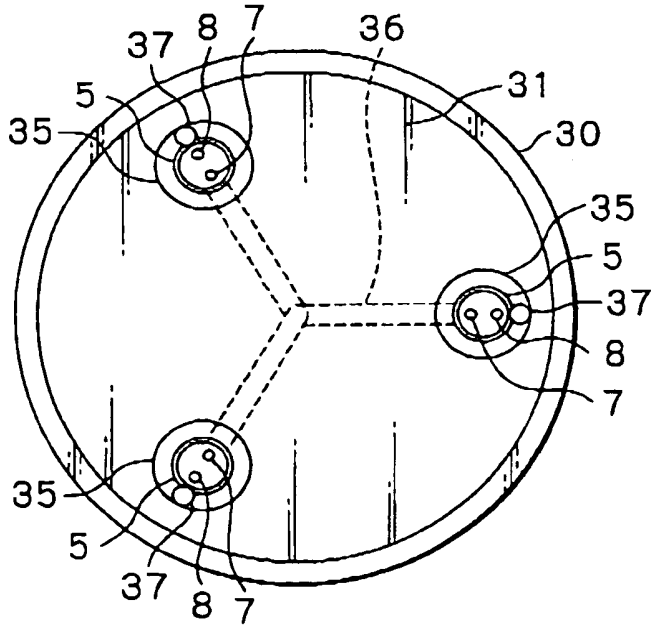


Fig. 18

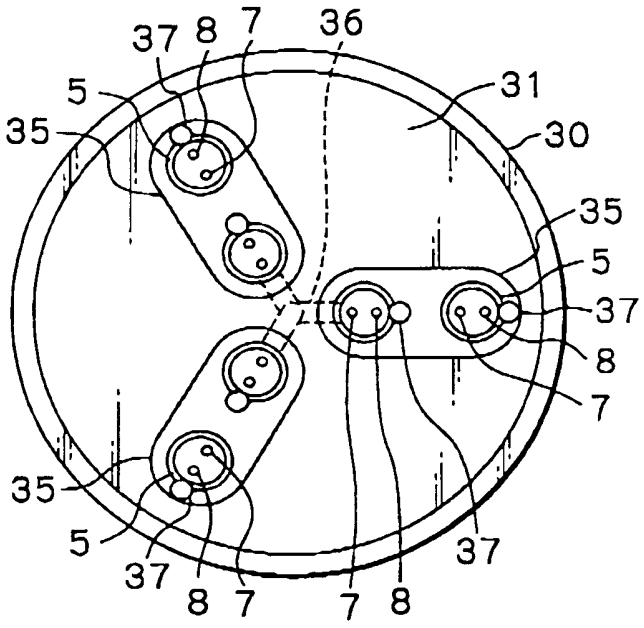


Fig. 19

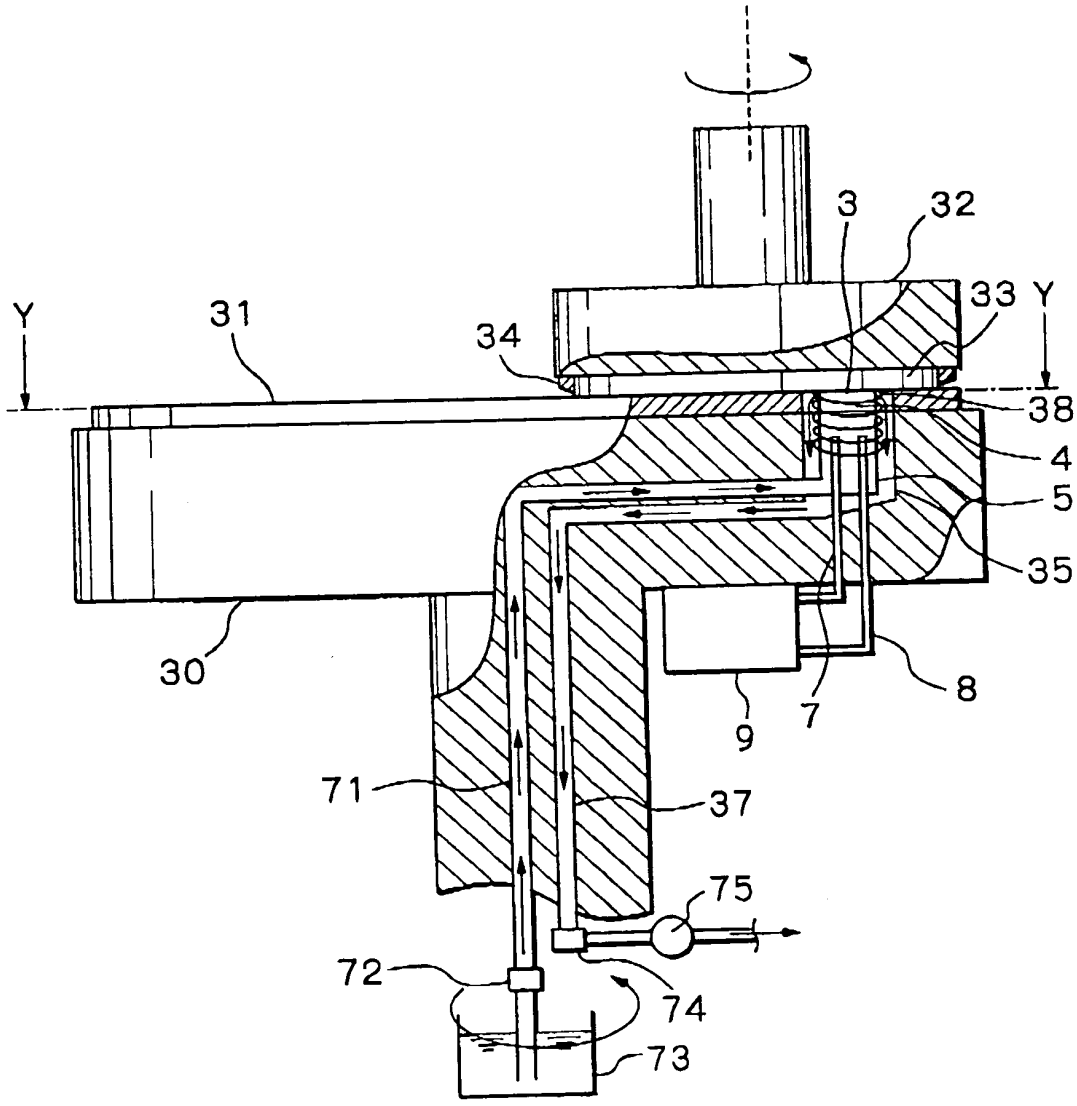


Fig. 20

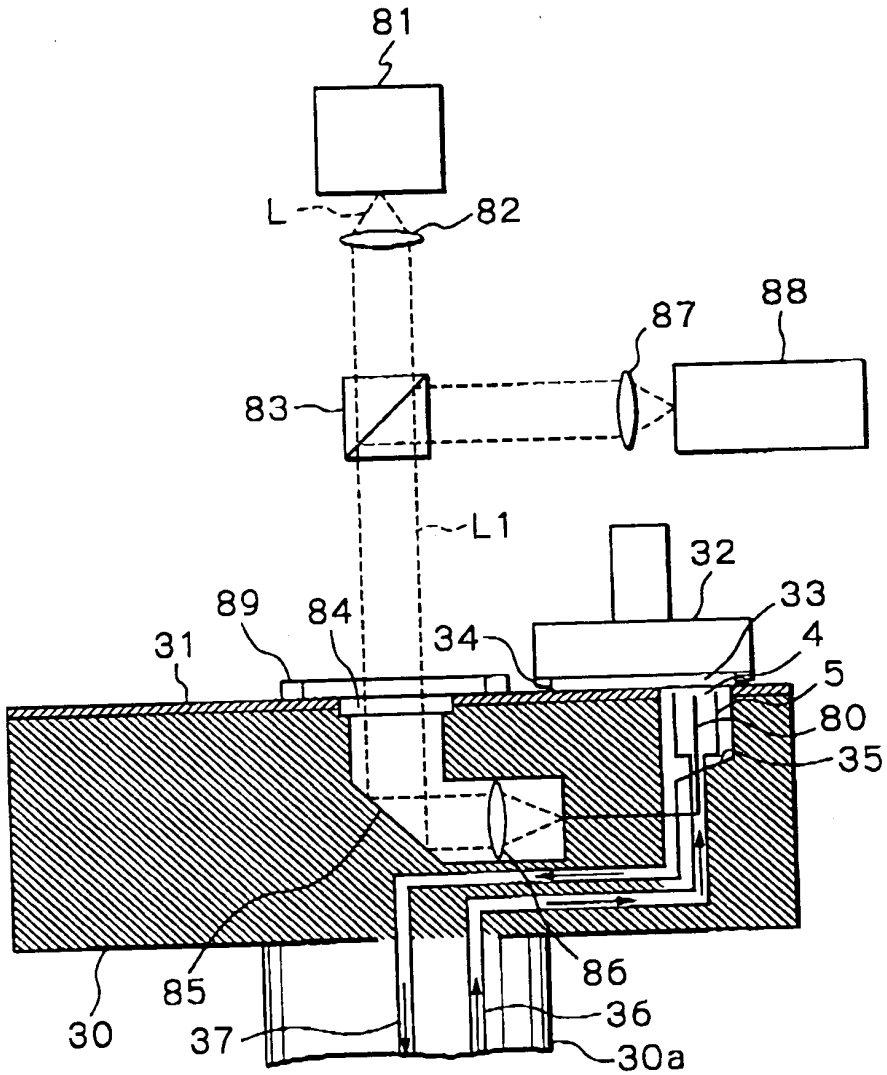


Fig. 21

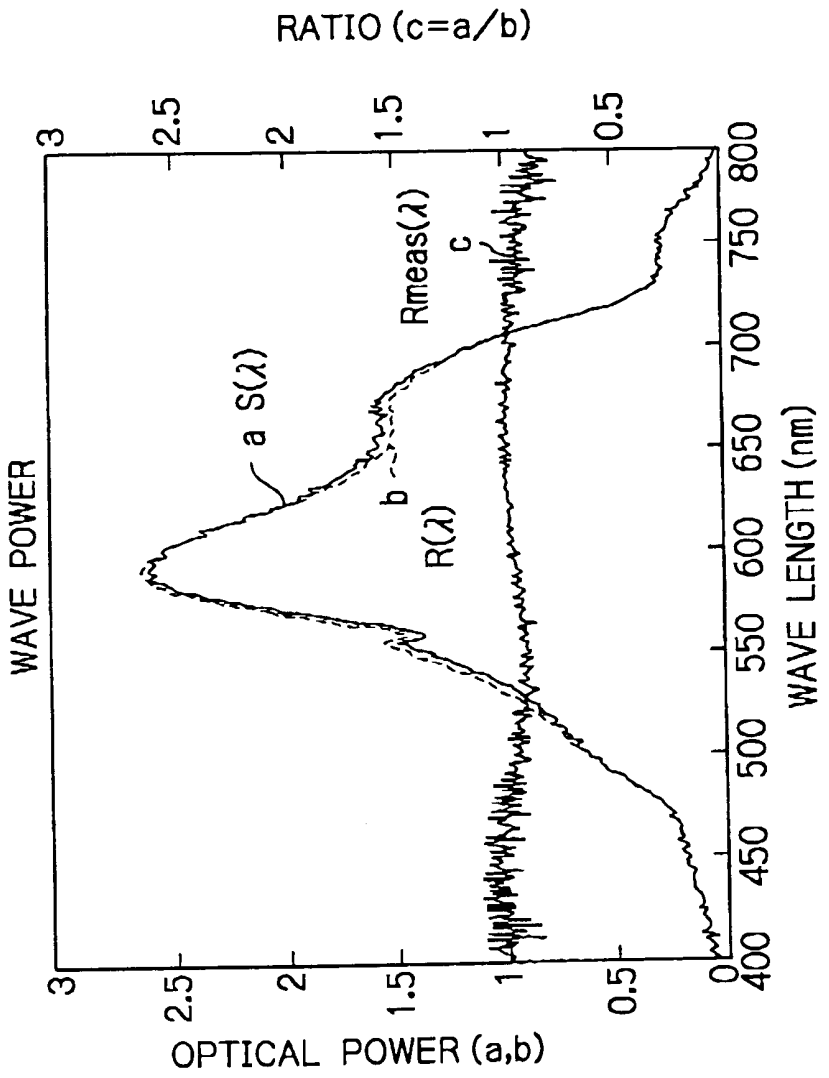

RATIO (c=a/b)
WAVE POWER
OPTICAL POWER (a,b)
WAVE LENGTH (nm)
a S(λ)
b
R(λ)
Rmeas(λ)
c
3
2.5
2
1.5
1
0.5
0
400
450
500
550
600
650
700
750
800

Fig. 22

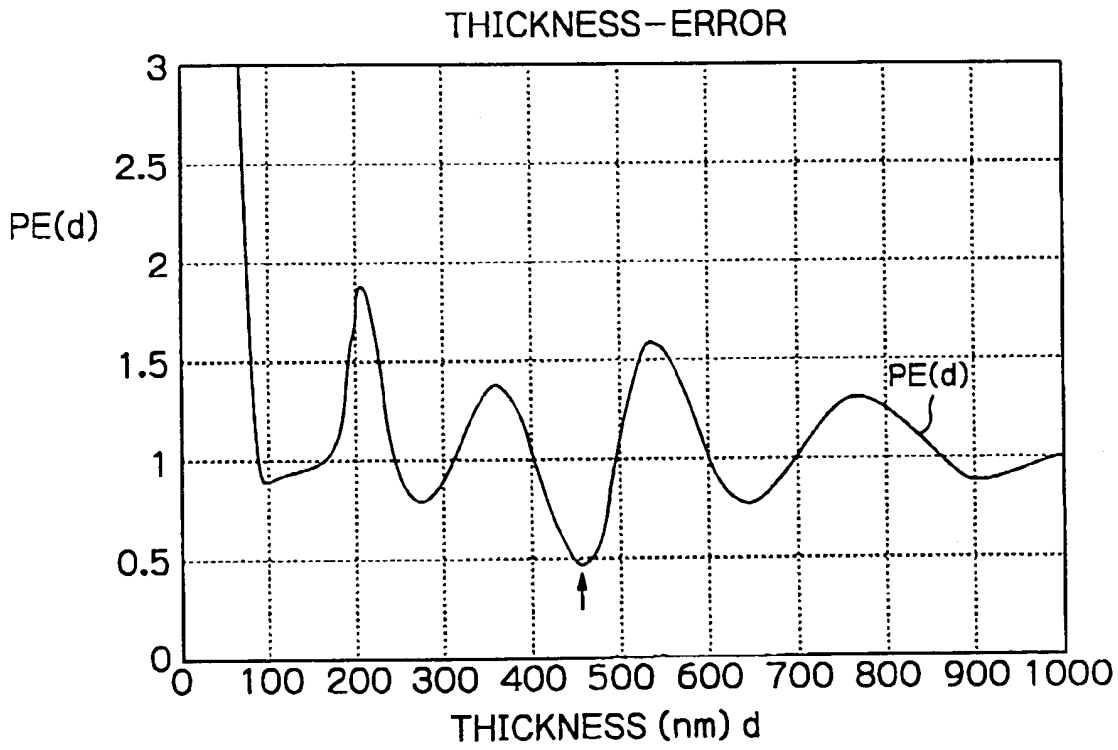

THICKNESS-ERROR
PE(d)
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
700
800
900
1000
PE(d)
THICKNESS (nm) d

Fig. 23

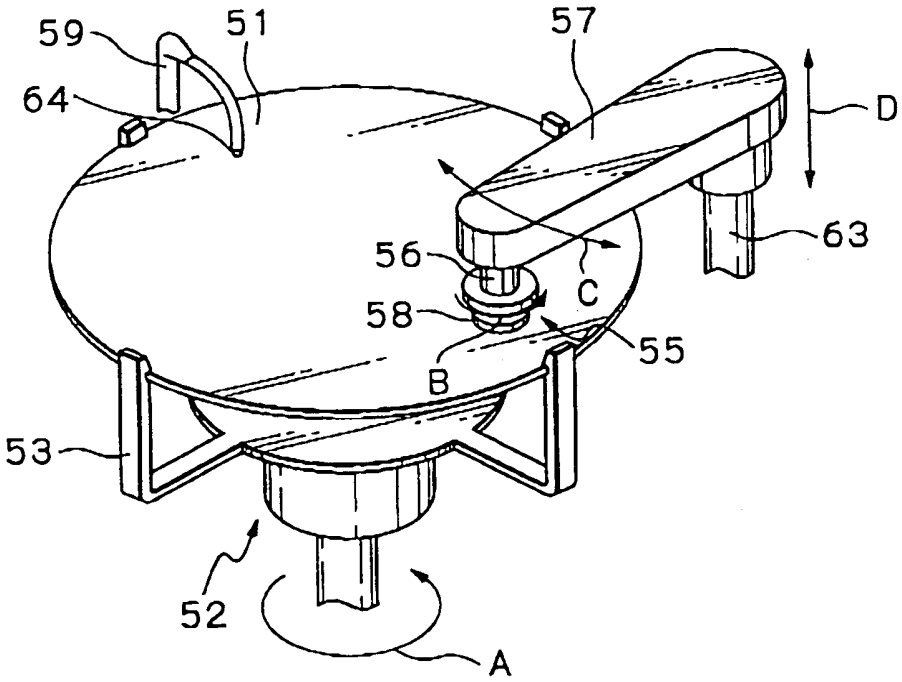


Fig. 24

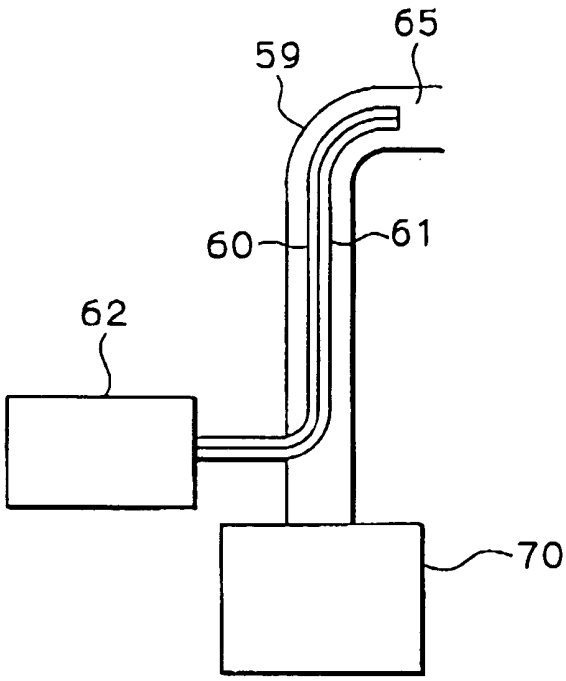


Fig. 25

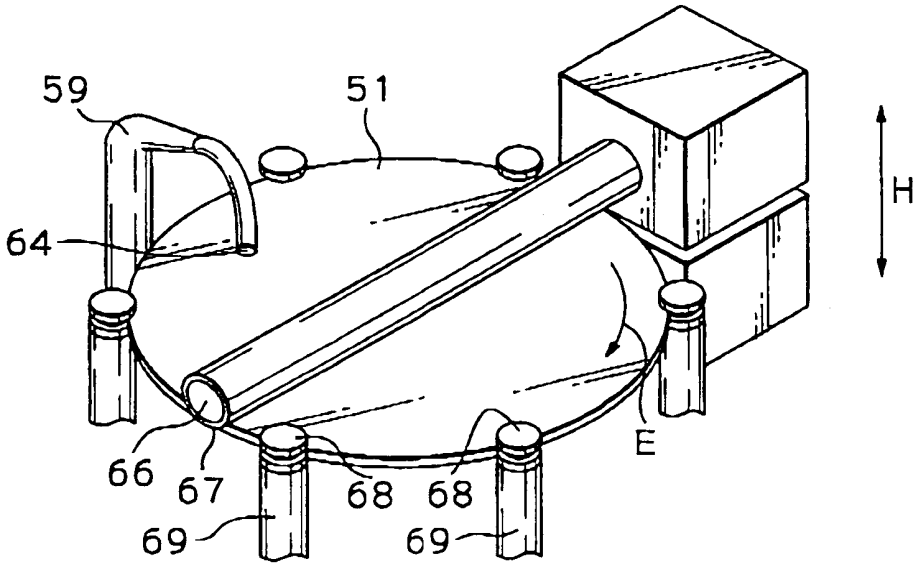
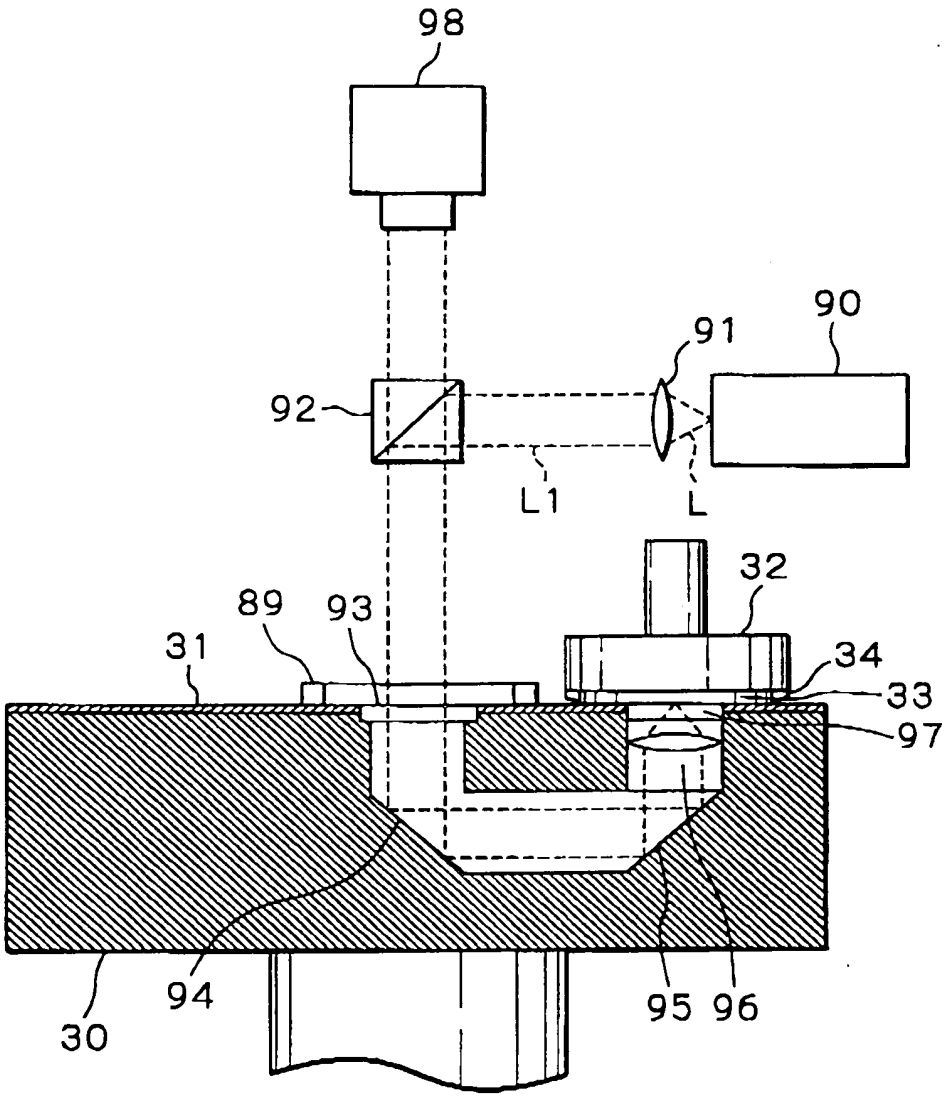



Fig. 26